Detecting biodiversity changes along climatic gradients: the IBISCA-Queensland Project

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ABSTRACT

The IBISCA-Queensland project established 20 permanent plots over an altitudinal range of 300 m to 1100 m above sea-level (d.s.l.) in rainforest within Lamington National Park, south-east Queensland. Four replicate plots were established at each 200 m interval, representing an average temperature change between altitudes of about 1.5°C – a full range of approximately 7.5°C. The project aimed to identify which animal and plant groups are likely to be most sensitive to climate change and which ones can best be used as indicators for monitoring such change. Full vegetation analyses were carried out at each plot and basic climatic and soil data collected. Over an 18 month period insect collections, using a wide-range of trapping methods, were made and specific projects carried out by more than 55 scientists from 14 countries. This paper summarises the history and goals of the project and the general 'IBISCA' model within which it was conceived. Site locations are presented, as is an outline of the specific trapping programme and more specific projects carried out within the broader objectives of IBISCA-Queensland. The strengths and weaknesses of the IBISCA approach are discussed. The first comparative syntheses are anticipated and a broader context for future work is defined. ☐ *IBISCA, Lamington National Park, climate change.*

The estimation of local diversity of terrestrial arthropods presents many difficulties if the goal is a 'complete' or near complete tally of species. Where this has been attempted, processes of gradual discovery and identification over unde- fined but long time scales have been envisaged. Measures of such alpha diversity are important but, in the face of rapid environmental change through anthropogenic activities from land clearing to global warming, are simply too slow and uncertain to contribute to the development of considered, data-based management respons- es to such threats. Although measures of alpha- diversity may prove elusive, this is not the case when we attempt to measure location-to-location contrasts in diversity. The comparative method is well suited to estimating species turnover from place to place (beta-diversity), because such turnover is a relative rather than an absolute measure. The standardisation of target taxa and survey methods against a well-thought-out experimental design is one such comparative approach.

Detailed information on arthropod diversity, particularly when matched by coincident botanical and mycological data, potentially provides unparalleled power for detecting beta- diversity in terrestrial ecosystems. The substantial demands associated with sorting large samples of arthropods into many orders, families, genera and species (or their 'morpho'- equivalents) in an age of restricted availability of taxonomic expertise has meant this potential has seldom been fully realised (Kitching 1994). Such multi- taxa approaches, until recently, have been few, extended and generally 'slow to product' (see Basset *et al.* 2003, and references therein).

In 2003, Yves Basset, Bruno Corbara and Hector Barrios initiated a new way of approaching such problems when they established the first IBISCA Project which compared arthropod assemblges in the canopy and ground zone of a tropical rainforest in Panama. Initially an acronym for 'Investigations of the Biodiversity of Soil and Canopy Arthropods', we have applied the name 'IBISCA' to the approach that is characterised now by relatively short-term, multi-scientist and multi-national research projects rather than by the explicit ecological canopy: ground comparisons addressed in the Basset, Corbara and Barrios project. In effect, a multi-skilled team covering expertise in a wide set of target taxa is assembled to work against a fixed experimental design established to address a particular dimension of heterogeneity. The fixed design means that whatever data are generated within the subprojects of individual scientists or teams of scientists can be legitimately compared across taxa and collection methods.

To date, three of the four of IBSCA projects have been conducted in rainforest. A fourth, contrasting project, is on-going in temperate, managed forest in central France.

In Panama, extensive comparisons were made of the diversity within lowland rainforest at ground level with that in the forest canopy overhead (Basset *et al.* 2007). During IBISCA- Queensland (this paper) biodiversity comparisons along an altitudinal gradient were made as a means of establishing a baseline for further studies on the likely impacts of climate change. A similar altitudinal gradient was the basis of IBISCA-Santo held in Vanuatu in 2006 (Tardieu & Barneoud 2007). The further IBISCA project in the Auvergne, France (2008-2010), targeted managed deciduous woodland. Future projects in both rainforest and other woody ecosystems are currently under discussion.

Diversity, Climate Change and the Need for Monitoring

There can be little rational doubt that the Earth is currently undergoing an unprecedented period of rapid warming, almost certainly as a result of elevated levels of so-called greenhouse gases in the atmosphere generated by human- related activities (Intergovernmental Panel on Climate Change 2007). There is growing evidence that this is having direct effects on biodiversity (Steffan *et al.* 2009) through changes of range,

local extinctions, disruptions of interspecific interactions and the modification of ecosystem-level processes. Such climate-driven changes are, of course, superimposed on communities already stressed by other anthropogenic modifications such as land clearing, other forms of pollution and the deleterious effects of introduced species (Department of Environment and Heritage 2004, Westoby & Burgman 2006, Steffen *et al.* 2009). Arthropods are proving to be particularly sensitive monitors of such climate-driven changes, reflecting a complex of features including their short longevities, ectothermic physiologies, relatively low levels of mobility and the tight inter-connectedness of species within communities.

Currently we assume that particular localities on the face of the Earth have associated with them a more or less characteristic set of species. Ecological communities of similar structure recur in places presenting similar environmental conditions within particular biogeographic regions. This statement is the logical basis for the science of community ecology. As climates change, so what we now think of as characteristic climatic 'envelopes' will shift (Westoby & Burgman 2006). Not all taxa that currently occur in a particular place will respond in the same fashion. Some will shift their distributions, others will simply remain where they are until conditions become inimicable for them and they will become extinct, while others may be able to adapt to the new conditions. In addition, species which currently do not occur in a particular location may invade as they follow changes within their particular envelopes of physiological tolerance. The synthetic consequence of this is that the composition of communities will change and re-assortments may well occur, generating new combinations the like of which we have not previously encountered. Of course, this process of re-assortment and subsequent redefinition of ecological communities has occurred frequently through geological time. What is novel in the case of the current episode

of climate change is the rate at which we expect this to occur and that, in contrast to changes over geological time, there are self-conscious scientific observers and managers.

Placing these ideas into the pragmatic context of conservation, means that some of our basic precepts have to be re-thought. In Australia, the (often unwritten) baseline for conservation policy is the so-called 1788 approach. This is the notion that we should strive, through policy and management, to preserve as much as possible of the continent in the state in which Captain Cook found it. This has served us well to date. The much-touted CAR (Comprehensive, Adequate, Representative) approach (JANIS Technical Working Group 1995) to the establishment of the national estate of reserved lands is based upon this idea. The 1788 approach assumes that nothing has changed upon the landscape other than what European settlers have done to it physically and biologically. The underlying capability of the land to maintain the set of ecosystems and the biodiversity they contained in 1788 is assumed to be still extant. In fact, processes such as soil erosion, salination, changed drainage regimes and so on may well have imposed irreversible changes upon Australian landscapes but, with a dash of optimism, each can be seen as a set of local events. However, under climate change this is patently an untenable view and management policy needs to adapt accordingly.

Changes in policy settings and management interventions can only ever be as good as the underlying data and scientific understanding on which they are based. Our ability to adapt conservation actions to a changing climate demands adequate and informed monitoring of what changes are occurring across adjacent climates. To do this, we need to know which taxa of the almost unlimited range which we *could* monitor are most likely to show sensitive and interpretable responses to even small amounts of environmental change. We need to identify a 'predictor set' (Kitching *et al.* 2000)

of taxa which we are confident will act as an early warning system for climate-driven impacts upon biodiversity. There is likely to be a unique predictor set of this kind for each ecosystem type. The only logical and robust way to identify such a set of taxa is following an intensive baseline survey. Such a baseline survey and the subsequent identification of predictor taxa has been the goal of the IBISCA-Queensland project, focussing on the extensive remnant rainforests of south-east Queensland.

Altitudinal Gradients and Climate Change

Altitudinal gradients present many different environmental and biological shifts, and are useful tools for understanding ecosystem dynamics. In the last decade the use of altitudinal gradients has developed as they have become recognised as useful study systems, containing many eco-tones in a small geographical area. Altitudinal gradients have been used to investigate species turnover and the mechanisms behind patterns in diversity and community structure (Bravo *et al.* 2008, Gagne 1979, Hebert 1980, Lieberman *et al.* 1996, Beck & Chey 2008, Beck *et al.* 2008). Climate change is also being investigated using altitudinal gradients, where gradients in environmental variables such as temperature and precipitation occur in the same area, within the same forest or soil types (Shoo *et al.* 2006). This has been especially relevant in climate change science where altitudinal gradients have been utilised either as analogues for latitudinal climate change, or as a way of examining climate change impact on assemblages along such gradients (Hodkinson 2005).

In summary, altitudinal gradients are of particular value in the study of the interaction between climate and diversity for several reasons:

1. gradients can be chosen which minimize uncontrolled environmental variation so that the impacts of climate are more apparent;

2. adjacent climates can be examined over relatively modest distances making comparative studies practicable; and,

3. an entire set of study sites can be established within a particular biome (such as rainforest).

Climate change will elicit a complex array of responses, which makes it difficult to form predictions or generalisations about future impacts based on the responses of any one study group. Many studies have used either latitudinal or altitudinal transects as gradients to examine how the distribution of groups, such as insects, are changing in response to climate change (Andrew & Hughes 2005, Botes *et al.* 2006, Inouye *et al.* 2000, Progar & Schowalter 2002). A number of abiotic factors, such as temperature and precipitation, change consistently with altitude and these factors influence the altitudinal distribution of arthropods. One of the major criticisms of altitudinal studies has been that the environmental and biological factors may all be inter-correlated. Conversely, these correlations give altitudinal gradients potential to explore these physical and biological factors and make predictions about how they will change and how biota will respond.

Temperature lapse rate. Temperature decreases as elevation increases; dropping by about 1.5°C in dry air for every 200 metre increase in elevation (Jacobson 2005). Fundamentally this is because air expands as it rises and loses heat in consequence. This is basic physics. The lapse rate will change only if there is water condensation in the air, or local addition or removal of heat from either above or below. From above heat exchange may occur due to solar radiation on the one hand, or conduction into overlying cold air, in the other. From below, conduction may occur to or from a soil surface having a different temperature. In any particular environment, therefore, local conditions such as seasonality, diurnality, topography, aspect, precipitation and cloud level (Lookingbill & Urban 2003) may effect lapse rate but these effects are likely to be minor.

The spatial relationship between atmosphere and surface factors is complex and is expected to be altered by climate change (Pepin 2001). Temperature lapse rate may decrease with climate change because of increased condensation of

water from the more humid atmosphere: accordingly, high altitude sites are likely to experience warming at a greater rate than lowland sites (Foster 2001). Arthropods will, almost certainly, be strongly influenced by temperature, which can affect the distributions of both insects and their host plants.

Precipitation. Precipitation generally increases with altitude (Fowler *et al.* 1988). Moisture levels are highest where the cloud cap sits due to horizontal precipitation through direct contact between cloud and soil or vegetation. It has been suggested that climate change is predicted to increase the average cloud cap altitude on mountain tops. Temperature increases will change the altitude at which water vapour will condense, altering moisture levels dramatically and, potentially, drying cloud forests (Pounds *et al.* 1999, Still *et al.* 1999, Williams *et al.* 2003). This 'conventional' analysis to some extent understates the complexity of water/atmosphere interactions and contradicts received wisdom on temperature effects (see above). A warmer 'greenhouse' world will hold more water as vapour in the atmosphere, potentially increasing the facility for cloud and mist formation. Higher levels of water held in the atmosphere will also modify the adiabatic lapse rate to as little as 0.15°C per 100 m (American Meteorological Society 2000) with, presumably, consequential effects on the average level of the cloud base. The observed drying of cloud forest may at least in part reflect changes in local water dynamics as underlying lowland forests are cleared (Lawton *et al.* 2001).

Altitudinally, precipitation regimes can be confounded by local factors such as seasonality and topography (Henry 1919). Arthropods can be affected physically by precipitation, for example, through desiccation due to drought, or indirectly through effects on host plants (Schulze *et al.* 2001). Variability of precipitation patterns has a direct impact on arthropod species' abundance and reproductive success, with some species exhibiting greater success with increased rainfall whilst others are more successful during dry periods (Speight *et al.* 1999).

THE IBISCA-QUEENSLAND PROJECT

We elected to study an altitudinal gradient in order to examine changes in biodiversity across a set of adjacent climates driven by the changes in altitude. This involved the study of the biodiversity of sets of replicated sites at five different altitudes above sea level. These altitudes represent a series of five adjacent climates each separated by 200 m of altitude (equivalent to approximately 1.5°C steps in average temperature regime).

Lamington National Park contains by far the largest remnant of undisturbed rainforest within the Australian subtropics. The region is also identified as a national 'hotspot' of biological diversity and is known to be a point of overlap between characteristic temperate south-eastern biota and more tropical northern elements (the MacPherson-Macleay overlap zone; Burbidge 1960). The Lamington National Park is also one of the properties making up the 'Gondwana Rainforests of Australia' World Heritage Area (see Kitching *et al.* 2010, for a comprehensive set of general accounts).

Based on the kraznozem soils of old Tertiary volcanoes, the 23000 ha of the Lamington National Park is dominated by rainforests ranging from rich warm subtropical vegetation to the species-poor forests of the highest elevations ('cool temperate rainforest') (Hutley, 2006). Intermixed with the dominant krasnozem soils are areas of more acidic rhyolitic soils which are poorer in nutrient and drainage but which also maintain rainforest in wetter areas. The IBISCA study was restricted to areas of krasnozem soils. We were able to establish a set of twenty sites representing replicated sampling points at five elevations along an altitudinal gradient within continuous, undisturbed rainforest within a single major catchment of the park. All sites were located on the same geological substrate.

Over a series of major field excursions, we sampled the vegetation, fungi and invertebrates along this gradient throughout the year. In addition, a number of parallel subprojects examined specialist taxa, collecting procedures or ecological processes.

The project set out to collect baseline information from the region and to use it to test the following hypotheses:

1. there is an altitude-related turnover in biodiversity operating within the forest under examination;

2. some taxa, or elements within taxa, will show more dramatic or clear-cut changes along the altitudinal gradient than will others;

3. these taxa have potential for monitoring future changes in climate;

4. ecological processes which are driven by particular taxa will change in degree or intensity along the altitudinal gradient;

5. species or groups of species at the highest altitudes are, potentially, most at risk under scenarios of future global warming; and,

6. a monitoring approach based on a thorough baseline assessment along an altitudinal gradient is likely to provide a powerful future management tool.

These activities comprised the IBISCA-Queensland Project.

The project was conceived following Kitching's participation in the earlier IBISCA-Panama project and developed during a follow-up visit to the USA as a Queensland-Smithsonian Fellow. Griffith University in partnership with the Queensland Museum, Queensland Herbarium, SEQ Catchments, the National Parks Association of Queensland and the Global Canopy Programme (Oxford, U.K.) developed the proposal which subsequently received major support from the Queensland Government under the National and International Research Alliances Program. Matching funds from the participating partners allowed the first field expedition to be mounted in October 2006.

In total, more than 50 research scientists and students participated in the project assisted most ably by over 70 volunteers. The scientists originated from 14 different countries.

DESIGN AND METHODS

Site Selection, Location. Lamington National Park was established in 1915 to preserve an area of upland forest located just north of the Queensland/New South Wales state border. With some later additions it now comprises 23000 ha dominated by broad-leaved rainforest. Extensive and important areas of dry and wet sclerophyll forest and sclerophyllous heath also occur within the park. The physical and current climatic environment of the region is described by Strong *et al.* (2011). The vegetation has been studied extensively over many years (Hopkins 1975, Olsen & Lamb 1988, McDonald & Thomas 1990, Laidlaw 2009). Comparable ecosystems in New South Wales are described at length by Floyd (1990).

Within the national park one of the principal catchments is that of Canungra Creek which rises close to the border escarpments and drains to the north. It has western and eastern branches which converge at about 400 m elevation. This catchment has a relatively uniform substrate (see Strong *et al.* 2011) and is also accessible over much of its length. Accordingly this was the location of choice for our study.

Within the West Canungra Creek catchment we were able to identify an extensive area of continuous rainforest vegetation from the extreme northern limit of the park at about 300 m a.s.l. to the Queensland/New South Wales border at about 1100 m a.s.l. Along this gradient we established five sets of four sites at approximately 300, 500, 700, 900 and 1100 m a.s.l. respectively (Table 1, Figure 1). This design regards the five altitudes as treatments with four more or less independent replicate sampling sites within each treatment. All sites were located within a

single catchment and hence, in a strict statistical sense, our results lead to conclusions only about forest within this catchment. The forest types within the catchment, however, are examples of widely distributed subtropical rainforests and we are confident that the baseline information we have will have wide relevance (see Discussion for further comments).

The twenty study sites were chosen against the following criteria:

1. each site should be accessible on foot;
2. each site should allow the establishment of a permanently marked central 20 m × 20 m vegetation plot;

TABLE 1. Labels, locations and altitudes of the 20 sites of the IBISCA-Queensland transect.

Designation	Latitude	Longitude	Altitude (m a.s.l.)
IQ-300-A	-28.148	153.137	267
IQ-300-B	-28.155	153.139	282
IQ-300-C	-28.151	153.138	260
IQ-300-D	-28.142	153.133	248
IQ-500-A	-28.216	153.142	560
IQ-500-B	-28.213	153.103	514
IQ-500-C	-28.210	153.187	474
IQ-500-D	-28.207	153.137	471
IQ-700-A	-28.188	153.121	746
IQ-700-B	-28.192	153.124	775
IQ-700-C	-28.193	153.128	748
IQ-700-D	-28.204	153.129	748
IQ-900-A	-28.234	153.141	904
IQ-900-B	-28.238	153.145	950
IQ-900-C	-28.240	153.149	944
IQ-900-D	-28.227	153.131	920
IQ-1100-A	-28.258	153.159	1141
IQ-1100-B	-28.259	153.162	1142
IQ-1100-C	-28.260	153.167	1106
IQ-1100-D	-28.262	153.170	1140

3. each site should be within undisturbed rainforest;
4. each site should have the same soil type and aspect;
5. sites should be at least 300 m apart at each elevation; and,
6. sites should not be riparian.

Naturally such a set of requirements could not be wholly prescriptive but, as shown in Table 1 and Figure 1, these requirements, by and large, were met.

Environmental Data Collection. As a basic part of the project, climate stations were established at each altitude. In addition temperature and humidity data-loggers were located at both ground level and in the canopy at each of the twenty sites. A single set of soil samples was taken within each of the twenty sites and submitted to a series of chemical and physical analyses. Strong *et al.* (2011) present details of these methodologies and the results obtained.

Vegetation and Fungal Surveys. As each site was established, a central galvanised steel post was erected to which a permanent location label was welded. The exact location and altitude of this central locator post was recorded (Table 1). A baseline vegetation plot was established comprising a 20 × 20 m square quadrat centred on the reference post. Within that area, all trees greater than 5 cm dbh were marked, measured and identified. In addition, a list of all vascular plants occurring within the plot was made. The results of these vegetation surveys are presented by Laidlaw *et al.* (2011).

In addition to these surveys of the vascular plants, Dr Elizabeth Brown (Royal Botanical Gardens, Sydney) carried out surveys of bryophytes. Further, the Queensland Mycological Society, under the leadership of Nigel Fechner (Queensland Herbarium), undertook surveys of fungal fruiting bodies based in and adjacent to the sampling sites.
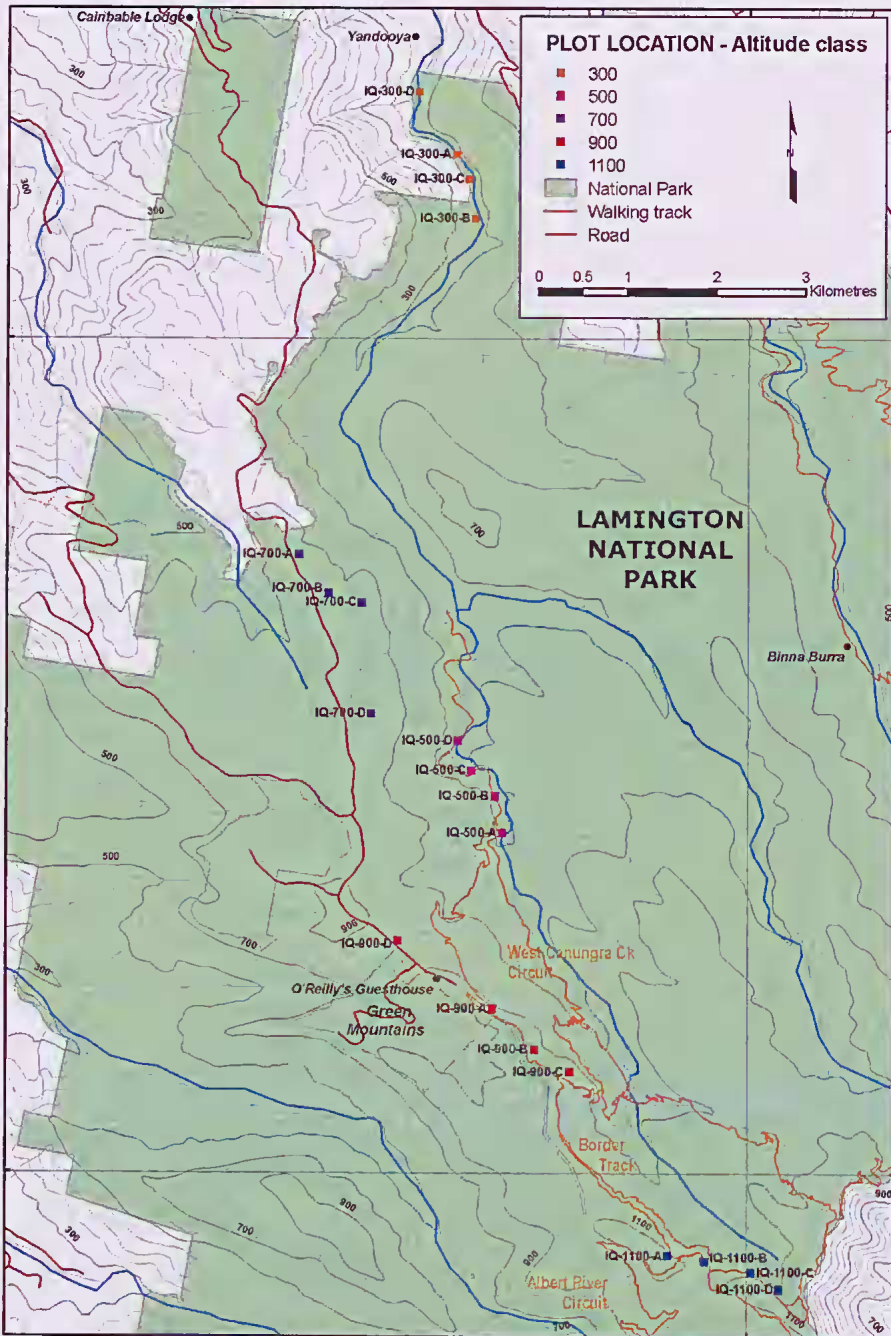
FIG. 1. Map showing the location of the IBISCA-Queensland transect and the distribution of plots along it (prepared by Rosemary Niehus, Queensland Herbarium).

TABLE 2. Trapping and projects carried out during IBISCA-Queensland (§ 700-1000 m only, at 50 m altitude intervals

Trapping Method/ Project	Pre-Project	Oct-06	Jan-07	Mar-07	Jul-07	Jan-08	Scientist(s)
Foundation							
Vegetation surveys	✓	-	-	-	-	✓	Laidlaw, Macdonald, Hunter
Climate data	-	throughout					Putland, Kitching
Baseline methods							
Malaise traps	-	✓	✓	✓	✓	-	Lambkin
Flight intercept traps	-	✓	✓	✓	✓	-	Monteith
Light traps	-	✓	-	✓	-	✓§	Kitching, Ashton, Maunsell
Pitfall traps	-	✓	✓	✓	-	-	Staunton, Putland
Bark spraying	-	✓	-	✓	✓	✓	Burwell, Nakamura, Wright, Thompson
Canopy knockdown	-	✓	-	-	-	-	Floren
Litter extraction	-	✓	✓	✓	-	-	Putland
Yellow pan traps	-	✓	-	✓	-	-	Putland
Other projects							
Beating	-	✓	-	✓	-	✓	Ødegaard
Canopy leaf quality & herbivory	-	-	-	-	-	✓	Kitching, Putland, Laidlaw, Hunter
Thysanoptera studies	-	✓	-	✓	-	-	Mound, Tree
Hole-nesting insects	-	✓	✓	✓	-	-	Morris
Dung-beetles	-	✓	✓	✓	✓	-	Monteith, Menendez
Bark fauna	-	✓	-	✓	-	-	Schmidl, Bittner
Ants & herbivory	-	✓	-	-	-	-	Bito, Novotny
Host specificity in herbivory	-	-	-	-	-	✓	Bito
Social insect surveys	-	✓	-	✓	-	-	Corbara, Burwell, Leponce, Orivel, Roisin, Delsinne
Spider surveys	-	✓	✓	✓	✓	-	Raven, Baehr
Dolichopodidae	-	✓	-	✓	-	-	Bickel
Pollination studies	-	✓	✓	✓	-	✓	Boulter
Galls in the canopy	-	✓	-	✓	-	-	Barbosa da Silva, Ribeiro
Mollusc surveys	-	✓	✓	-	-	-	Stanisic, Carless
Xylophagous Coleoptera	-	✓	-	-	-	-	Curletti
Earthworms	-	✓	-	-	-	-	Dyne
Flower/insect interactions	-	✓	-	-	-	-	Frame
Geometridae	-	-	-	✓	-	-	Leveque
Mite studies	-	✓	-	✓	-	-	Walter, Proctor
Fungal surveys	-	throughout					Fechner, Queensland Mycological Society
Moss surveys	-	-	-	✓	-	-	Brown
Decaying wood biomass	-	-	-	-	-	✓	Putland
Soils	-	-	-	-	-	✓	Putland

Baseline Trapping and Individual Projects. Drawing on experience from previous IBISCA projects, it was decided that a core activity of IBISCA-Queensland would be repeated sets of trapping using a range of standard trap designs. These are summarised in Table 2 which also indicates in which seasons they were applied.

The basic trap designs used are described in detail in Kitching *et al.* (2005). Most trapping methods were applied on at least three occasions in an attempt to capture seasonal variability. Canopy knockdown using pyrethrum insecticide was applied only in October 2006. Further details of the duration and disposition of these traps are presented by individual authors elsewhere in this special issue.

Responsibility for these standard trapping regimes and the processing of the catches has been a central responsibility of the Project Team. In addition, participating scientists carried out a wide range of more specialised surveys across the IBISCA sites which, on occasion, involved using duplicate sets of traps or other additional trap designs. These are summarised in the lower part of Table 2.

Labelling and Databasing Protocols. Participants from the Queensland Museum (primarily Christine Lambkin and Karin Koch) developed a detailed set of protocols for labelling and databasing the collected samples. Every sample collected was given a unique number for ease of subsequent tracking. Numbers were attached to recording sheets for participants to add to samples collected in the field. Ultimately, some 4375 such sheets were completed by participants in the project, and the localities entered into the Queensland Museum database. Standard specimen labels were prepared for all samples, and made available to all participants through the IBISCA-Queensland website. Also provided on the website were duplicate sample labels, sorting sheets, identification labels and all sample data for the October, January, March and July surveys. To date, over 8,500 identified specimens are registered in the database. These standardised methods and the project-wide database were used by all participants and all sub-projects. This consistency in procedures across the project provides the ability to combine data in novel ways to explore complex patterns, and the benefits of this approach are displayed in many of the papers presented in this volume.

Sorting and Curating. In the first instance, based on priorities established at a scientific workshop in April 2007, samples have been partly sorted to seven major arthropod groups and the residual catch. To this end all Heteroptera, Thysanoptera, Coleoptera, Diptera, Hymenoptera - ants, Hymenoptera - non-ants, and Araneae have been sorted and removed from all baseline methods for all seasons, with the exception of light traps and samples from March 2007 for which sorting is still ongoing. Sorted individual groups have been dispatched to specialist taxonomists for further sorting. In other cases, selected taxa and sampling methods have been prioritised by particular workers. Lepidoptera from light traps, Diptera from Malaise traps, a range of taxa from beating samples, and beetles from pitfalls, bark sprays and intercept traps have been targeted. The outcomes of some of these endeavours are presented in this special issue. We also are in receipt of specific returns on selected taxa such as Collembola, Thysanoptera and Tephritidae.

This Volume. This special issue of the *Memoirs of the Queensland Museum* presents basic data from the IBISCA-Queensland project that became available by mid-2009. It cannot be a complete account of our results – indeed, the idea of 'completeness' for such an extensive and multi-dimensional project is elusive. Nevertheless, it presents early results for what is a major study of its kind in Old-World rainforests. For Australasian rainforests it bears comparison only with the IBISCA-Santo

(Vanuatu) (Tardieu & Barneoud 2007) project which was carried out between the first two major field trips of the IBISCA-Queensland project. The basic idea and design of the overall IBISCA Programme is presented in this paper. Strong *et al.* (2011) outline the climate and soil properties of the study sites. Two papers summarise the vegetation characteristics of the altitudinal gradient. Laidlaw *et al.* (2011) present the characteristics of the vegetation with special reference to altitude-to-altitude turnover. Boulter *et al.* (2011) summarise the reproductive phenology of the flora. The remainder of the papers refer to the arthropod surveys carried out within or adjacent to the study sites. Boulter *et al.* (2011) present results on the ordinal distribution of insects encountered in Malaise and flight intercept traps. Ødegaard and Diserud (2011) summarise results obtained from beating surveys of the sites for Coleoptera, Hemiptera and Mutillidae. Staunton *et al.* (2011) compare patterns encountered among three predatory taxa – the ants, predatory beetles and spiders. A series of papers tackle single taxa encountered along the transect. These include the Formicidae (Burwell & Nakamura 2011), the moths (Ashton *et al.* 2011), Collembola (Greenslade *et al.* 2011), thrips (Tree & Mound 2011), orsolobid spiders (Baehr *et al.* 2011), spiders of the genus *Opopaea* (Araneae, Oonopidae) (Baehr 2011), Diptera collected using Malaise traps (Lambkin *et al.* 2011). Finally two papers tackle insect/plant interactions. Ribeiro and Barbosa (2011) examine vertical profiles of the occurrence of galls along the altitudinal transect and Bito *et al.* (2011) describe the interactions between ant abundance and herbivory at different altitudes.

DISCUSSION

Towards Syntheses

The underlying scientific imperative for this project has been to obtain information on the way the diversity and distribution of a variety of plant and invertebrate taxa change along a continuous altitudinal gradient within subtropical rainforest. This is basically an exercise in the measurement of beta-diversity from altitude to altitude within the forest. As such it is quintessentially a comparative exercise. This is by no means the first such comparative exercise which has been carried out. However, the advantage presented by the IBISCA methodology is that all data returns can legitimately be laid alongside each other and subjected to rigorous comparative analysis. The underlying common experimental design to whatever target taxa are studied, using whatever trapping methods, gives a statistical power to the analyses which unplanned meta-analyses cannot possess. This having been said, what we present in this volume is a series of single (or few) taxa descriptions based on one or a small number of trapping methods. As such we cannot claim yet to have fulfilled the promise of the IBISCA methodology.

What will emerge from these studies are synthetic outcomes in which subsets of data combining results for different taxa and/or trapping methodologies are combined to answer questions the importance of which will transcend the patterns observed for any one approach. The set of such synthetic outcomes is open-ended but we anticipate it will include:

1. IndVal (Dufrene & Legendre, 1997) analyses for a wide range of taxonomically defined data-sets to define a statistically useful multi-taxon 'predictor set' for the future monitoring of the impact of climate change on diversity;

2. comparative analyses of the relative importance of 'common' and 'rare' species in the detection of pattern in rainforest biological assemblages (see e.g. Gaston 2008);

3. key differences and similarities within altitudinal patterns (and, by inference, sensitivity to climate change) in taxa belonging to different guilds (herbivores vs predators; detritivores vs herbivores; ground dwellers

vs canopy dwellers, etc); and,

4. the utility and efficiency of different sampling methods in obtaining 'rapid' assessment of biodiversity change (cf. Kitching *et al*. 2001).

Other syntheses will no doubt emerge as our results stream matures.

Only One Catchment?

There is no avoiding the fact that our current set of results relate to one catchment within a single national park exhibiting but one set of vegetation characteristics. If it takes a project of this magnitude to characterise the biodiversity of a single catchment within a single set of eco-systems within just one geographical region, is there any realistic likelihood that we can develop general tools for understanding bio-diversity pattern and its likely response to climatic (or any other form of environmental) change? The answer is a resounding, yes!

The value of the set of results which have emerged and will continue to emerge from the IBISCA-Queensland project is that they represent a yardstick against which other less complete sets of data can be compared and assessed.

Building on the patterns observed in particular taxa as measured by specified sampling protocols within the IBISCA-Queensland study, we can examine other locations with much greater efficiency and focus. We add hastily that such efficiency and focus is now possible only because of the breadth and comprehensiveness of the IBISCA-Queensland project. A first step forward is to expand sampling within the Lamington region – to other catchments, other aspects, other substrates, to validate (or otherwise) the generality of the project's results. Already, based on ant work, we know the general altitudinal patterns hold up within other catchments and yet are modified, probably due to overland flow of colder, heavier air close to active drainages (Burwell & Nakamura 2009; C. Burwell pers. comm.). This generality and its topographic modifications needs confirmation using other

contrasting taxa (such work is in progress) yet can be very focussed and clinical, based on the outcomes predicted by the IBISCA-Queensland results.

The fact remains, nevertheless, that baseline surveys such as those undertaken in IBSICA-Queensland will be necessary for other key ecosystems. However robust are the patterns observed in subtropical rainforest within Lamington National Park, it is unreasonable to expect them to be anything other than a striking contrast to results we might expect along an altitudinal gradient within sclerophyll woodland or even fully tropical rainforest, let alone grassland or savannah.

'Missing' Taxa

One of the underlying principles behind the IBSICA-Queensland project was that it provided a means by which the scattered resources represented by the taxonomic establishment could be joined in a single enterprise to produce results far beyond those which any one specialist, collaborating with ecologists in the field, could hope to produce. Nevertheless, there is a national and global dearth of practising taxonomists and this shortage must be further viewed against our growing appreciation of just how diverse is life on Earth, and the appalling rates at which it continues to disappear. So how comprehensive was the taxonomic coverage achieved by the IBISCA-Queensland project. And how significant are any short-comings?

We achieved reasonable coverage of the Lepidoptera (although many families of micro-lepidoptera remain unstudied). Coleoptera also were adequately dealt with, in no small part due to the efforts of our Norwegian and German colleagues. Diptera have been analysed down to family level and several specialists are pursuing further resolution on selected families. The other mega-Order, the Hymenoptera, was covered patchily. We had five project specialists focussing on one family: the Formicidae. The project was fortunate to have specialist parti-

cipation for Collembola, Thysanoptera and Araneae. Acari also received some attention but, of course, this in no way matched (or could have matched) their vast known and anticipated diversity. In terms of gaps we had no participation from specialists in the Orthoptera or Hemiptera. In the second of these cases this was a serious deficiency which we are attempting to address. Other notable omissions were treatments of Psocoptera and aquatic groups: both diverse from place to place within this rainforest. Of course our general sampling regime did sample these and other groups and samples are stored for future analysis.

Ecologically the project managed to cover most major functional groups: herbivores, detritivores and free-living predators. The parasitoids remain perhaps the most significant deficit in our analyses if one takes such a functional viewpoint. Once again the material is there.

So what can one conclude from such a retrospective? Basically in developing any comparative approach to forest diversity, either to test fundamental questions or to provide management tools, we will be limited by available taxonomic expertise. One of the most pleasing aspects of the IBISCA-Queensland project to date, has been the emergence of a group of keen postgraduate students who are 'picking up' particular taxa and developing their own expertise and enthusiasm for future studies using these groups as tools.

The Latitudinal Context

The results available to date, from virtually all taxa that have been adequately analysed, there appears to be high, mid- and low-altitude specialists. Under even relatively mild climate-change scenarios some of these species will become of conservation concern. The management responses that may be needed to address these concerns will vary depending on whether the risk incurred is local or global. In a few instances – such as the dung-beetles – we already know sufficient about the wider distribution of the species concerned to judge just how serious this conservation concern should be. In almost all other cases, however, our knowledge of the wider distribution of taxa is either unknown or uncollated. In order to inform this question we need comparative studies on rainforest locations at different latitudes within Australasia. The basis for such studies already exists in some latitudes. Sets of sites are already established in far north Queensland and in New Guinea (S. Williams, V. Novotny pers. comm.). Other obvious locations for comparative transects are the Eungella massif, the Dorrigo/New England region of northern NSW and the Barrington Tops region of central NSW. The foci of survey work on such additional transects can now be informed by the results of the IBISCA-Queensland transect and can be more focussed and selective than was appropriate in the Lamington case. Research on Lepidoptera, Formicidae, Collembola and Coleoptera on some of these proposed transects has begun.

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spheric dynamics and temeprature lape rates, has been much improved following the comments of Dr Clyde Wild who refereed the submission. Any errors, of course, remain ours alone.

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